

Status of ICARUS Experiment at SBN

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for the **ICARUS** Collaboration

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The ICARUS (Imaging Cosmic And Rare Underground Signals) Collaboration at SBN

The full list of the Collaboration <https://icarus.fnal.gov/collaboration>



Catania (INFN and Univ.)
GSSI
LNGS
INFN Milano Bicocca
INFN Napoli
Padova (INFN and Univ.)
Pavia (INFN and Univ.)



Brookhaven (BNL)
Colorado State
FNAL
Houston
Pittsburgh
Rochester
SLAC
Southern Methodist Univ.
Texas (Arlington)



CINVESTAV



Spokesperson: C. Rubbia, INFN GSSI
more than 90 collaboration members

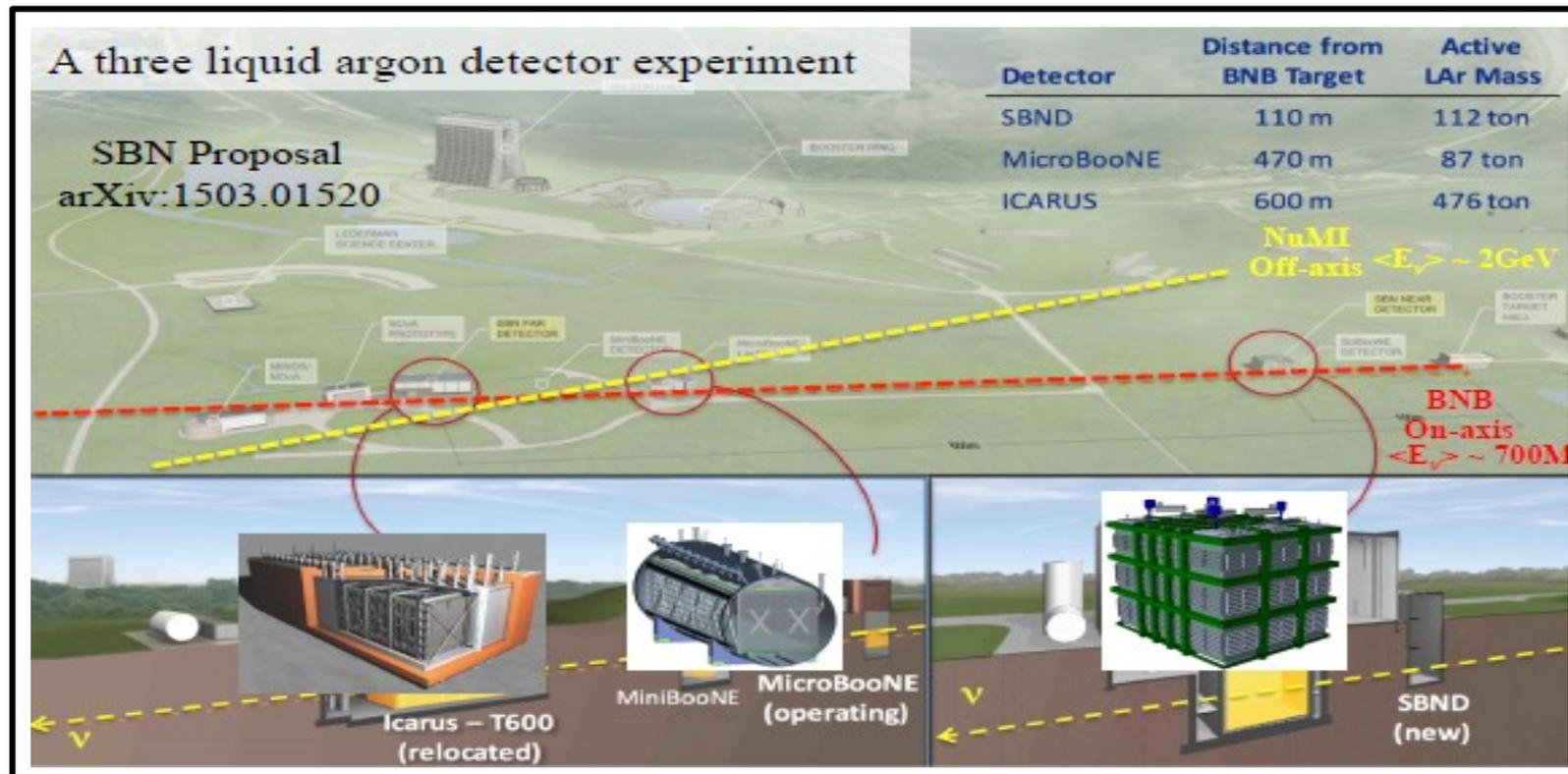
International Partner



Many thanks for the major contributions to the Far Detector cryogenics and cosmic ray tagger from our partners at CERN, INFN-Bologna, INFN-Lecce, INFN-Milano, INFN-Napoli, INFN-Genoa, INFN-LNS.

Short Baseline Neutrino (SBN) program

- Short Baseline experimental anomalies have been reported over the last 20 years.
- Common interpretation is as evidence for one or more additional, mostly “sterile” neutrino.

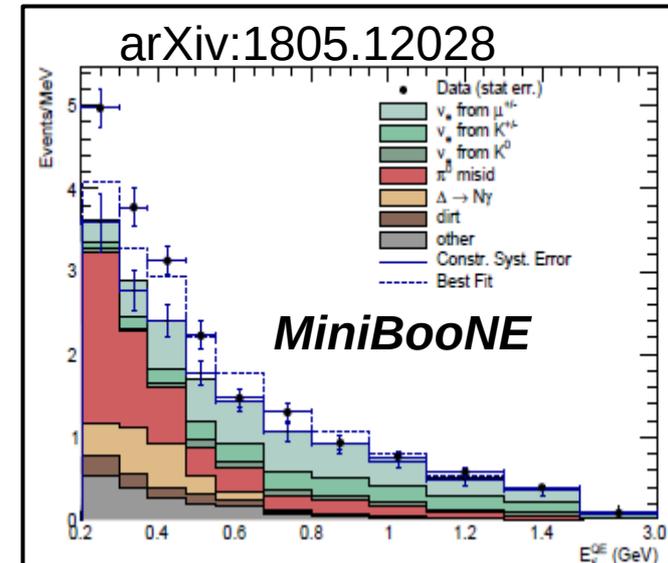


- The SBN Program is composed of three LArTPC detectors with the goal of definitively addressing the hints of eV-scale sterile neutrinos.

Physics motivation of SBN

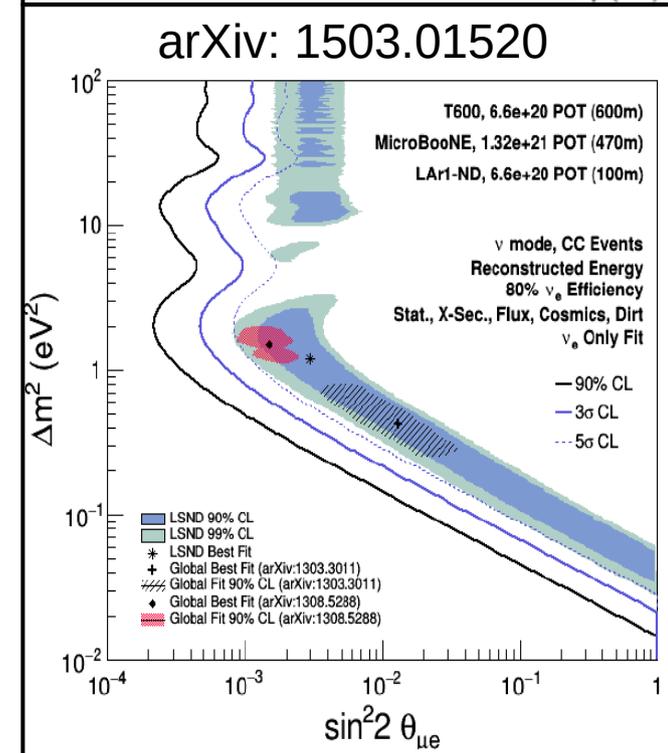
- **Resolve the low-energy excess anomaly**

- *Testing confused situation about the sterile neutrinos evidence shown by several experimental anomalies.*



- **Search for ν_e appearance and ν_μ disappearance**

- *Multiple detectors at different baselines are key for reducing systematic uncertainties with same target and same beam.*

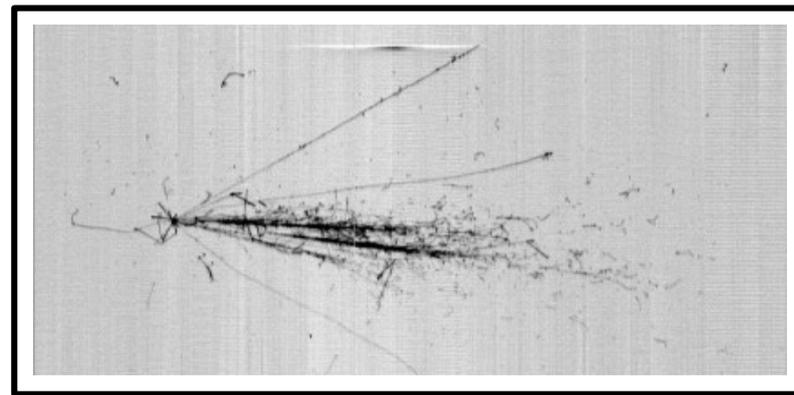
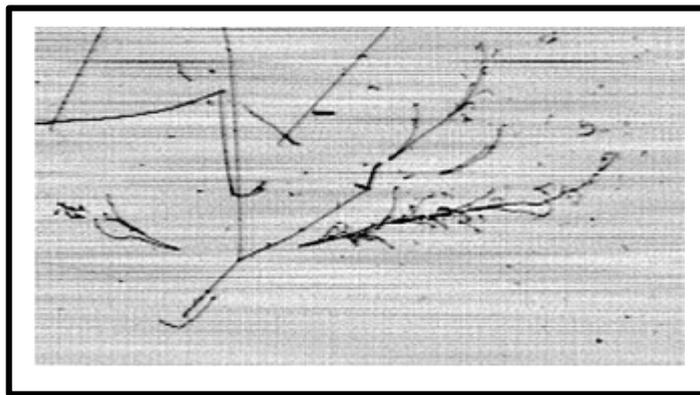


- **Preparation for future long-baseline neutrino experiment**

- *Neutrino-Ar cross-section, systematic uncertainties.*
- *Further R&D of LAr technology.*

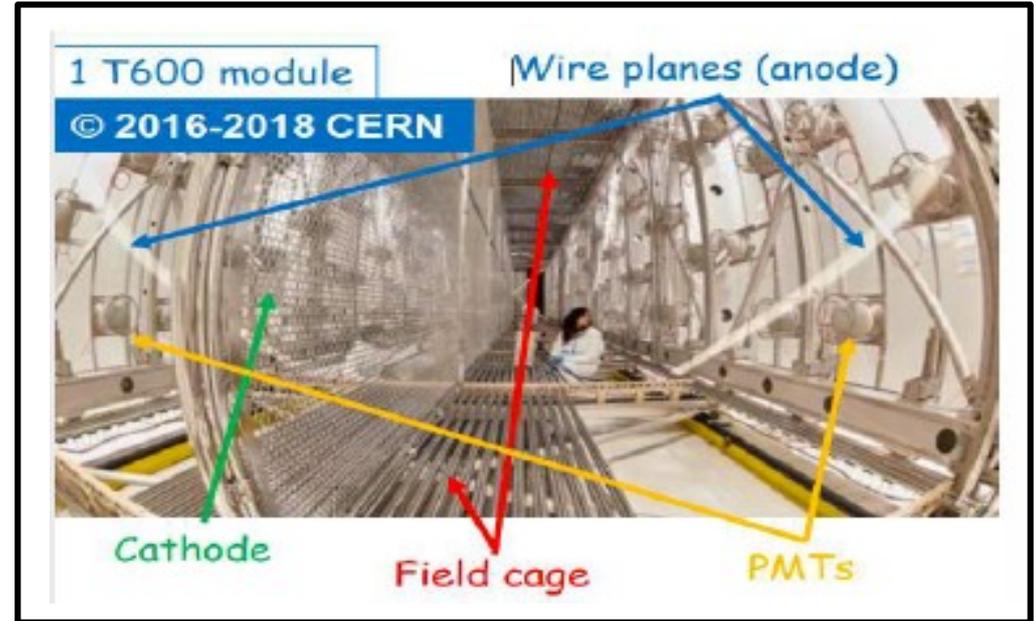
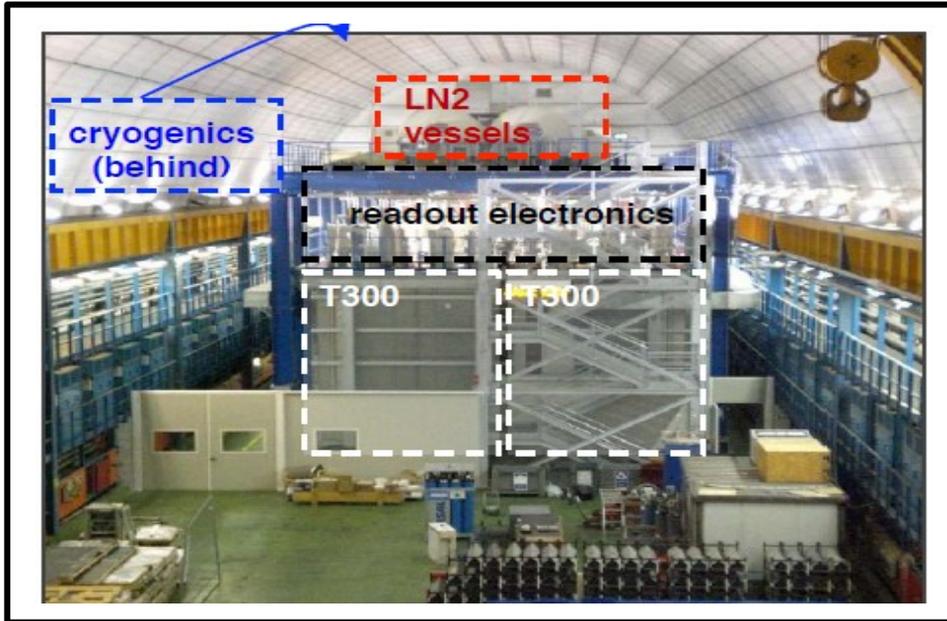
Liquid Argon Time Projection Chamber

- **LArTPCs (“electronic bubble chamber”)** are excellent detectors for neutrinos and nucleon decay :
 - 3D tracking reconstruction with high (mm^3) spatial granularity
 - Homogeneous, full-sampling calorimetry for contained particles
 - Electrons can drift for several meters in high purity argon
 - Scintillation light can provide fast signals for timing/triggering
 - LAr is dense and cheap: very large masses of detector possible



- **First proposed by C. Rubbia in 1977**
- *Extensive R&D at INFN and CERN culminated in first large-scale experiment in 2010.*
- *ICARUS-T600 operated at Laboratori Nazionali del Gran Sasso (LNGS) in Italy.*

ICARUS-T600 at LNGS



- **First large-scale LAr-TPC in a neutrino beam.**
- **Two identical module: each module size : $19.6 (L) \times 3.6(W) \times 3.9(H) m^3$; total LAr mass ~ 760 tons, active LAr mass 476 tons.**
- **Drift distance 1.5m, drift field 500V/cm \rightarrow drift time $\sim 1ms$.**
- **3 signal wire planes (2 Induction+Collection) with wire readout.**
- **Pitch and inter-plane distance both 3 mm; 400 ns sampling time; ~ 54000 total channels.**
- **74 (20+54) 8" PMTs with TPB wavelength-shifter coating.**

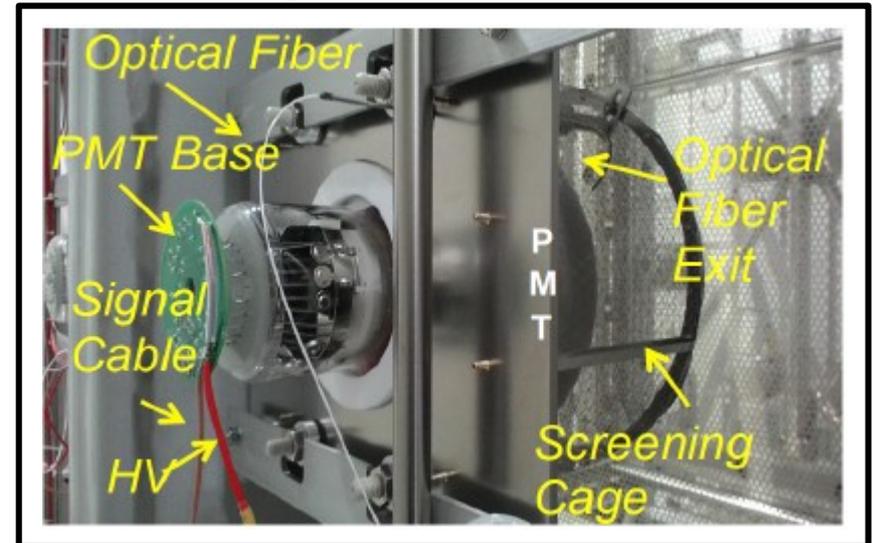
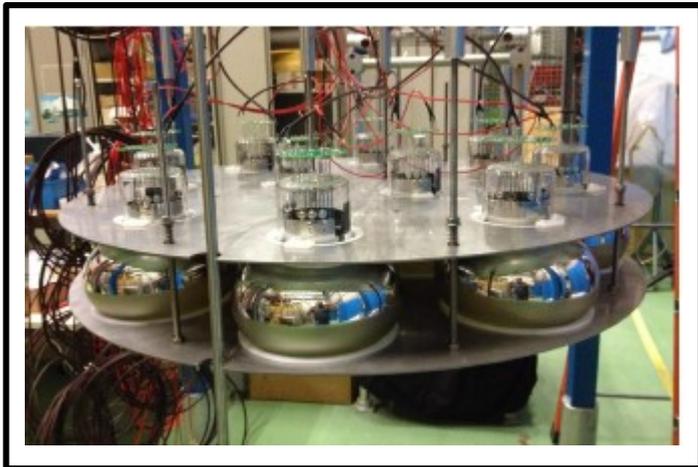
ICARUS at SBN: New experimental challenge

- ***ICARUS at FNAL is facing a more challenging experimental condition (surface) than underground condition at LNGS, one of the T300 detector ran on surface.***
- *Several additional (11 kHz of cosmic rays) events will be occurring continuously during the readout time window of T600 at SBN.*
- *3 m concrete overburden will remove contribution from charged hadrons/ γ 's.*
- ***To overcome the new experimental challenge, T600 underwent an intensive overhauling at CERN in the Neutrino Platform framework from 2015 to 2017, before shipping to US.***
- ***Several technology developments were introduced***
 - *new cold vessels, with passive insulation in addition to N_2*
 - *renovated LAr cryogenics/purification equipment*
 - *improvement of the cathode planarity*
 - *upgrade of the PMT system: higher granularity and ns time resolution*
 - *new faster, higher-performance read-out electronics*
 - *new CRT system: Top, Bottom, Side to reject the cosmic background*

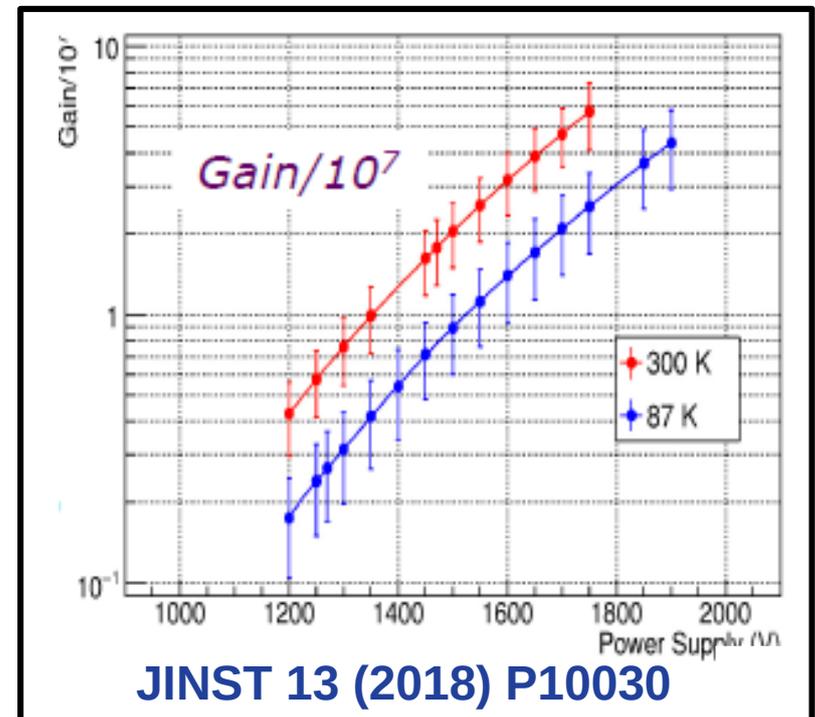
ICARUS-T600 Upgrade : Light Collection system

New photon detection system of ICARUS consist of

- 2x90 PMTs for each TPC (5% coverage, 15 phe/MeV)
- Good spatial resolution ($\leq 50\text{cm}$)
- $\sim \text{ns}$ timing resolution.



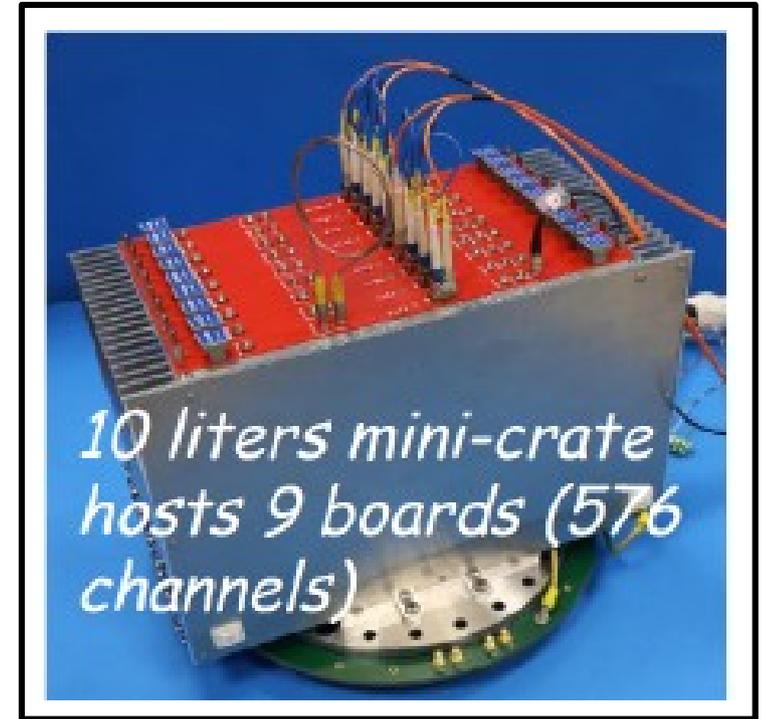
- All PMTs tested at room temperature in a dedicated dark room at CERN, 60 PMTs tested in LAr.
- PMTs were characterized individually at 300K and 87K.



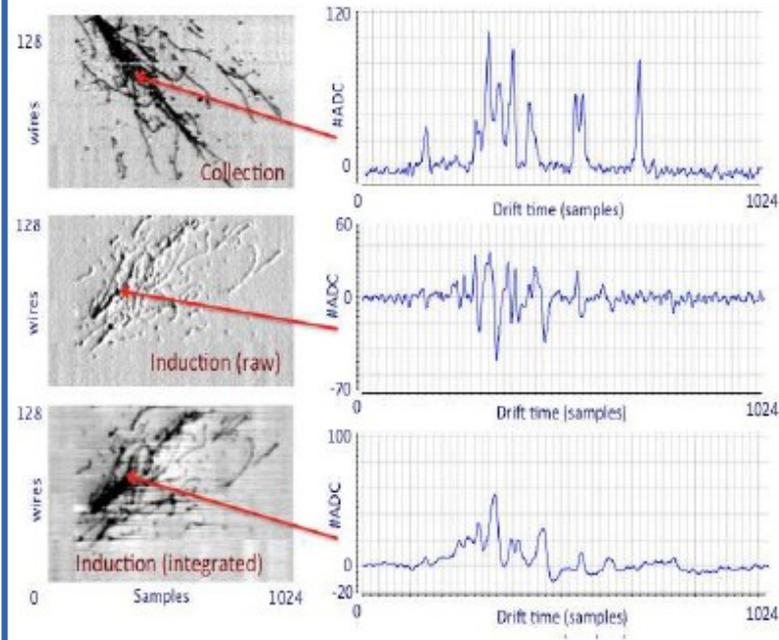
ICARUS-T600 Upgrade : TPC readout electronics

New TPC readout electronics

- Outside the cryostat
- Serial 12-bit ADC, fully synchronous in the whole detector.
- CAEN A2795 64-chan modules.
- **More compact layout: both analog+digital electronics hosted on a single flange.**



Tests on 50-liter TPC at CERN

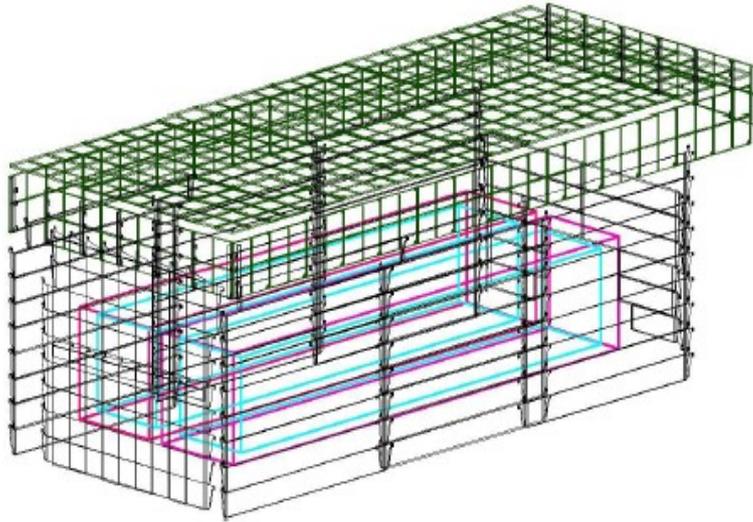


- **Electronics was tested on a small LAr-TPC test facility.**
- **Lower noise (~20% S/N improvement w.r.t to LNGS electronics).**

The Cosmic Ray Tagging system (CRT)

TOP

~ 400 m² : roof + angled parts



SIDES

~500 m² :on four slides



BOTTOM

~ 200 m² :already installed



- Surrounds the cryostat with two layers of plastic scintillators: 1100 m²
- Top - new construction (SiPM readout)
- Sides – repurposed MINOS veto system (new SiPM readout + electronics)
- Bottom (partial) – spare Double Chooz experiment veto modules (MAPMT)
- Tag incident cosmic or beam-induced muons with high efficiency (95%)
- Few nanoseconds time resolution -> direction of particle propagation via time of flight

ICARUS installation at FNAL: Status

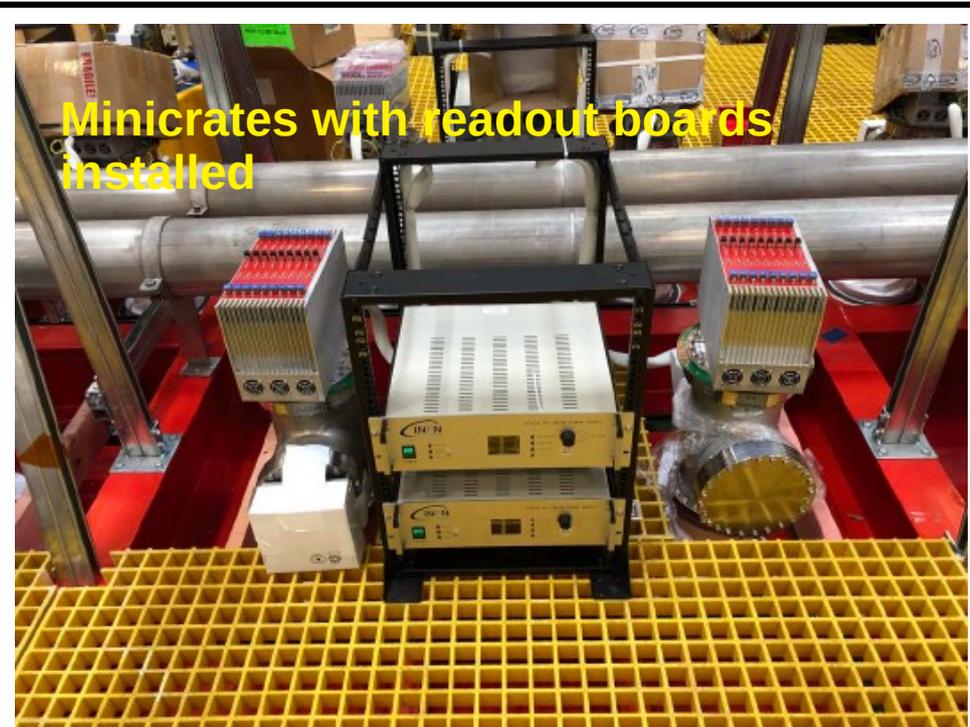
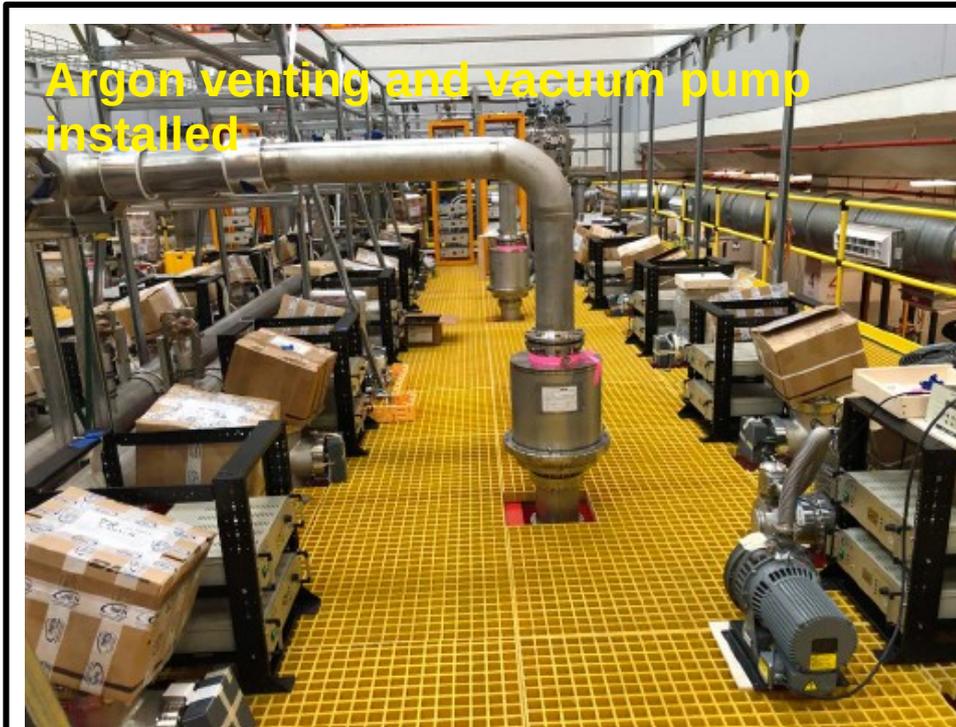
- *T600 installed inside warm vessel in August 2018.*
- *Installation of TPC/PMT feedthrough flanges and connectivity tests, completed by February 2019.*
- *Leak tightness tests completed.*
- *Top cold shields and top CRT support installed.*



- *Installation of proximity cryogenics essentially completed.*
- *The north part of the side CRT has been installed.*

ICARUS installation at FNAL: Status

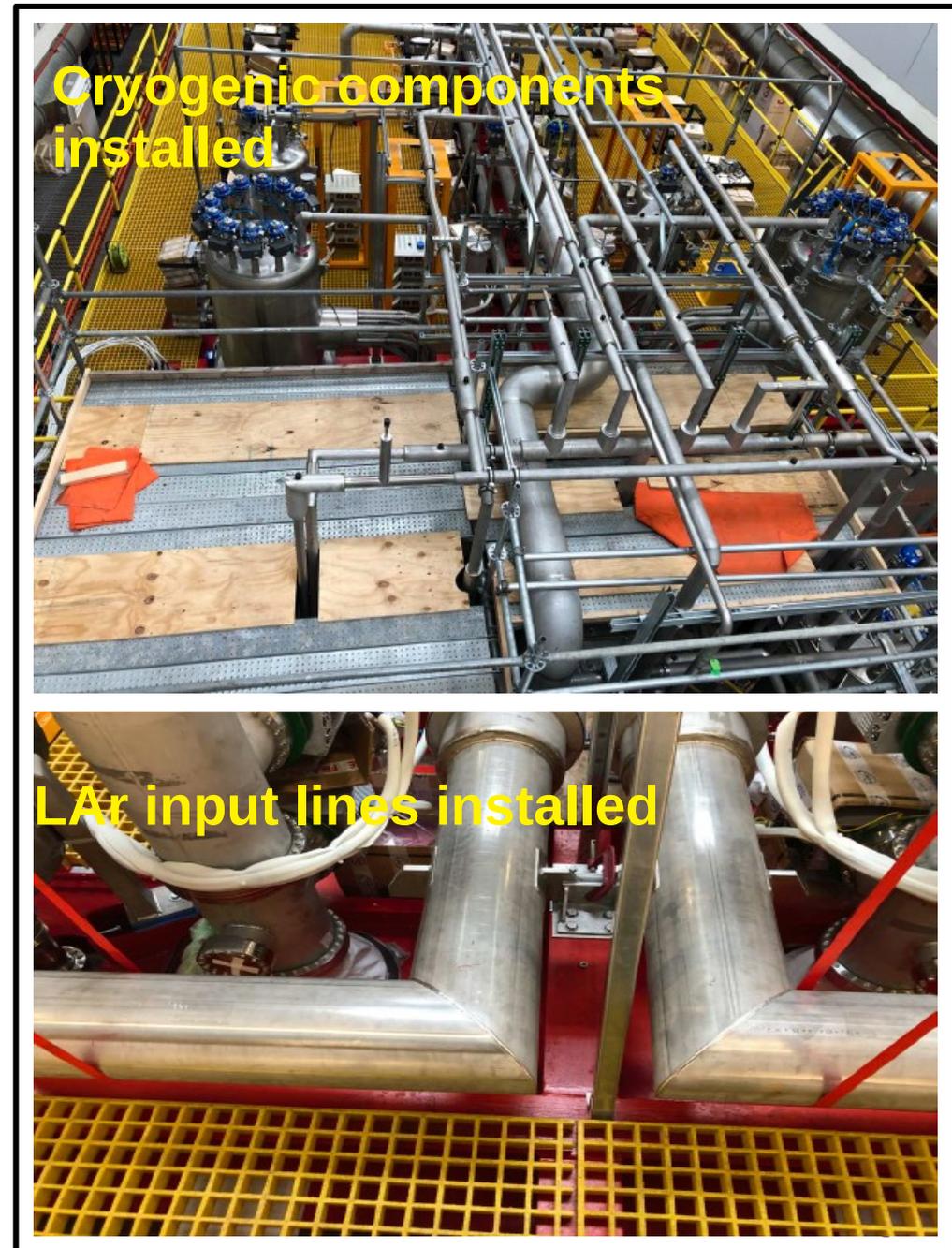
- ***All the wires readout electronics (minicrates, FE boards and power supplies) has been installed and verified.***



- ***After closing all the apertures of the cold vessels, when the internal volumes became dark, all phototubes have been turned on and checked for functionality.***
- ***All the 360 PMTs tested after installation and validated.***

ICARUS installation at FNAL: Status

- *Most of the cryogenic equipment and the transfer lines have been installed, welded and pressure tested.*
- *The vacuum system (for the shielding and the main volumes) is installed and ready to be operated.*



ICARUS installation at FNAL: Status



Director's Review in December 2018 recognized the great progress of SBN

ICARUS at FNAL : plan

- ***The mechanical installation of all detector components on the cold vessels is almost complete.***
- ***PMT electronics installation also to be completed during the summer.***
- ***ICARUS expected to be ready to fill by mid September.***
- ***Commissioning of CRT, DAQ, trigger and slow controls will follow.***
- ***Commissioning and data taking expected by the end of this year.***

Outlook

- *Successful 3 years run of ICARUS-T600 at LNGS matured LAr-TPC technology and ready for large scale neutrino experiments.*
- *ICARUS @SBN will be able to clarify the sterile neutrino puzzle by looking at both appearance and disappearance channels.*
- *ICARUS-T600 was extensively refurbished and is now being installed at SBN Far Detector building on the BNB beamline.*
- *Installation of the full coverage of CRT is under progress*
- *Detector cooldown expected on mid September of 2019.*
- *Hope for Neutrino @ICARUS by the end of this year!*

Thank You!

